Draft Guidelines for Licensed Suborbital RLV Operations with Flight Crew

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Introduction

FAA/AST regards flight crew as part of the flight safety system, in accordance with 14 CFR Part 431, when the crew has control over the safety of the vehicle and the capability of averting a potential hazard to the uninvolved public. Implementing regulations issued by FAA/AST under its statutory authority, 49 USC Subtitle IX, chapter 701, requires the FAA/AST to assess the flight crew's role in the mission related to public safety and determine if crew functions are integral to satisfying Part 431 safety standards (i.e., if the flight crew has the ability to control the vehicle or plays a role in the flight safety system).

The FAA/AST's primary regulatory responsibility is protecting the uninvolved public on the ground and in the air. Where a flight crew can affect vehicle operations, FAA applies licensing requirements to regulate the crew's ability to perform all necessary functions to protect the uninvolved public; that includes addressing crew qualification and training, environmental control and life support systems, fire detection and suppression, and human factors. The following Draft Guidelines for Licensed Suborbital RLV Operations with Flight Crew are meant to assist FAA/AST and RLV operators in meeting their regulatory responsibility when the RLV flight crew, whether on-board or on the ground, is part of the flight safety system.

Why are suborbital RLV flight crew guidelines necessary?

RLV mission licensing regulations contemplate crewed vehicles but only specify minimal RLV flight crew standards, such as those pertaining to crew rest. Other issues related to RLV flight crew survival are not addressed. Where crew survivability is critical to safe vehicle operation, the FAA needs to develop a regulatory program that addresses crew safety issues and vehicle operational requirements to sustain crew life. The development of these guidelines is a first step in generating RLV flight crew regulations.

To whom would these guidelines apply?

These guidelines would apply to the crew onboard a suborbital RLV when the crew is part of the flight safety system. These guidelines would also apply to crew remotely piloting an RLV on a suborbital mission, if they are part of the flight safety system.

What is the scope of these guidelines?

The guidelines focus on public safety by enhancing the safety of the flight crew on suborbital RLV missions only when the crew is part of the flight safety system. The guidelines address crew qualification and training, environmental control and life support systems, fire detection and suppression, and human factors. These guidelines are intended to complement other FAA/AST guidelines, such as those for Operations and Maintenance and the RLV Safety-critical Equipment List.

I. RLV Flight Crew Qualifications

1. An RLV flight crew member who exercises control authority over a vehicle that will operate in the NAS shall possess an FAA pilot certificate, and shall hold ratings in aircraft of comparable category, class, and type.

Rationale: The requirement to hold a pilot certificate and to hold ratings in a comparable type of aircraft ensures that the pilot in command will have received training and experience in similar aircraft and will have demonstrated the basic airmanship skills necessary for safe operations in the NAS.

2. RLV flight crew shall possess a valid FAA 2nd-class medical certificate.

Rationale: The safe operation of a piloted RLV can be affected by the health or medical condition of an RLV flight crewmember who is part of the flight safety system. One aspect of a flight crewmember's ability to perform safety-related functions is the physical and mental state of the individual. The FAA's Office of Aerospace Medicine (AAM), which includes the Civil Aerospace Medical Institute (CAMI), the medical certification, research, and education wing of the AAM, considers the medical qualification standards for 2nd-class airman certification to be adequate standards for an RLV pilot on a suborbital mission due to its inherently short duration. Class 1 medical certificates are required for pilots of scheduled airliners. Class 2 medical certificates are for commercial, non-airline duties. Class 3 medical certificates are for private pilot duties only. 14 CFR Part 67, which provides medical qualification standards for 1st-class, 2nd-class, and 3rd-class airman certifications, addresses standards for eye; ear, nose, throat, and equilibrium; mental, neurological, cardiovascular performance and the general medical condition for the purposes of pilot certification.

3. a) RLV flight crew shall be trained before being approved by the FAA to crew each mission. The RLV operator shall develop a mission- and configuration-specific training program for flight crew and define performance standards for successful completion.

Rationale: A well-planned training program will enhance safety by preparing the crew for the rigors of the specific vehicle and operational environments. Completion of a training program ensures that the operator focuses on crew proficiency, as a singular goal, as opposed to being in conjunction with vehicle testing when the crew has additional responsibility. The performance criteria must be met before every crewed mission.

b) The RLV operator's training program(s) shall include:

i. **Prior to crewing a design reference mission, the RLV flight crew shall receive vehicle and mission-specific training to cover all phases of flight by using a combination of the following: i) a method of simulation (operational and/or procedural), ii) an aircraft with similar characteristics for certain phases of the mission, iii) incremental expansion of the mission envelope, or iv) an equivalent method of training as determined by the FAA Administrator.**

   Rationale: In order to ensure an adequate level of safety for the mission, the flight crew shall be trained in the operations that they must perform during the mission and be familiar with the flight behavior of the vehicle. Training in the above will prepare the crew and help to ensure adequate public safety and health are maintained.

ii. **The RLV operator shall validate and verify the fidelity of all RLV flight crew training devices.**

   Rationale: The RLV operator needs to test and demonstrate that any device/apparatus used to meet the training program requirements has the fidelity to adequately represent the vehicle's configuration and mission and, therefore, provide realistic training to the RLV flight crew.

iii. **RLV flight crew training shall include nominal as well as non-nominal flight conditions. The non-nominal situations shall include, at a minimum, i) abort scenarios, ii) emergency operations, and iii) maintaining the safety of the uninvolved public in the event of a crew egress.**

   Rationale: This allows an RLV flight crew trainee to demonstrate competent understanding of vehicle systems, vehicle characteristics and vehicle capabilities. This guideline is analogous to §431.37 requirements for nominal and non-nominal mission dress rehearsals.

iv. **If the vehicle relies on multiple control and/or propulsion modes, then the training program shall include training in each mode, including the transition between modes.**

   Rationale: The flight crew needs to be capable of maintaining vehicle control as the transition from aerodynamic control surfaces to the reaction control system (RCS) occurs. Furthermore, the flight crew needs to be capable of maintaining vehicle control as the transition from one propulsion mode to another propulsion mode occurs.

v. **The training program shall be continually updated to include lessons-learned from training and operational missions. This shall be accomplished with a system to track revisions and updates.**

Rationale: The training program needs to capture lessons-learned as experience is gained. The RLV flight crew must be prepared for events/anomalies discovered during training and mission operations.

vi. **The RLV operator shall document the training completed by each crewmember and maintain the documentation for each active crewmember. The training shall be recorded in terms of mission cycles and phases of mission cycles.**

Rationale: Gathering and maintaining accurate documentation are vital for tracking and ensuring that crewmembers are up-to-date with their training requirements. Recording training in terms of hours is not necessarily germane to RLVs because RLVs are rarely in a condition of steady, level flight.

4. The RLV operator shall ensure that all RLV flight crew qualifications are current before undertaking crew responsibilities of an RLV.

Rationale: This ensures that all crewmembers are qualified and have received the necessary minimum training at the time of RLV operation.

II. Environmental Control and Life Support Systems (ECLSS)

1. The RLV operator shall provide adequate atmospheric conditions for all crewed areas:

a. The RLV operator shall monitor and control the composition and revitalization of the atmosphere to maintain safe levels for normal respiration for the RLV flight crew.

Rationale: Atmosphere must provide safe levels of oxygen and carbon dioxide to allow normal respiration. Because of normal human metabolic effluent, it is natural for carbon dioxide to accumulate and need to be removed.

b. The RLV operator shall monitor and control the pressure of the atmosphere to maintain safe levels for RLV flight crew respiration.

Rationale: An essential aspect of the body's ability to absorb oxygen from the air is the atmospheric pressure, specifically the partial pressure of oxygen (pO_2). For normal breathing, the pO_2 within the cabin should be kept between 19.5 kPa to 23.1 kPa to avoid the affects of hypoxia. Total pressure and the partial pressure of carbon dioxide should also be monitored.

c. The RLV operator shall have a contamination and particulate control system for the RLV flight crew.

Rationale: Atmosphere must be free from harmful or hazardous concentrations of gases or vapors. Particulate and contaminant control may also be needed to protect sensitive equipment from damage.

d. The RLV operator shall monitor and control the temperature of the atmosphere to maintain safe levels for the RLV flight crew.

Rationale: While humans can survive in a relatively wide range of temperatures, it is essential to regulate the temperature within the cabin or suit. Providing proper temperature controls ensures the RLV flight crew maintains a high degree of situational awareness to enable the RLV flight crew to perform its safety-critical functions. In addition, temperature control is needed to ensure that equipment is being kept within its normal operational environments.

e. The RLV operator shall monitor and control the humidity of the cabin atmosphere to maintain safe levels for the RLV flight crew.

Rationale: If the RLV flight crew depends on visual information through a window, humidity control is necessary to avoid windows fogging and condensation that can hinder the pilot's vision. Humidity control is also required to ensure that equipment is being kept within its normal operating environment.

f. The RLV operator shall monitor and control the ventilation and circulation of the cabin atmosphere to maintain safe levels for the RLV flight crew.

Rationale: Providing proper ventilation ensures the RLV flight crew maintains a high degree of situational awareness by reducing stagnant air, which may contain a build-up of carbon dioxide. Good circulation is also an important function for equipment cooling.

g. The RLV operator shall provide a redundant or back-up oxygen supply for the RLV flight crew.

Rationale: In the event of a failure of the primary atmospheric control system, the redundant or back-up system will supply oxygen for the RLV crew.

2. The RLV operator shall make provisions for stowage of all objects in the cabin, to avoid interference with the crew's operation of the vehicle during flight.

Rationale: This preserves the ability of the RLV flight crew to perform its safety-critical functions without being negatively affected by the environment.

3. The RLV operator shall design the crew environment to mitigate the effects of a vehicle decompression.

Rationale: If a decompression should occur, it could have serious physiological effects on the crew, including hypoxia, decompression sickness, hypothermia, and vaporization of tissue fluids.

Documents that provide guidance on Environmental Control and Life Support Systems include "Designing For Human Presence in Space: An Introduction to Environmental Control and Life Support Systems" (NASA RP-1324) and "Man-Systems Integration Standards" (NASA-STD-3000).

III: Fire Detection and Suppression

1. **Any crewed vehicle shall have the ability to detect and suppress a fire to prevent incapacitation of the crew and subsequent risk to the public.**

Rationale: Smoke from a fire can rapidly incapacitate a pilot or obscure the pilot's vision so that the vehicle cannot be flown safely. An RLV operator needs to be able to respond to a vehicle fire so that the vehicle does not pose additional risk to the public.

IV. Human Factors

1. Human factors shall be considered in the design of human-machine interfaces associated with RLV missions and operations so that the RLV flight crew can perform its safety-critical functions.

a. **Human factors engineering shall be applied to the design of human-machine interfaces (e.g., displays and controls) and mission design (e.g., allocating functions and workload).**

    Rationale: Human–related factors account for the majority of fatal aircraft accidents while aircraft system malfunctions are involved in a relatively small fraction of aircraft incidents and accidents. Some human factors-related lessons learned from aviation may be applicable to suborbital RLVs with a flight crew on board. Human factors considerations draw on multiple disciplines such as psychology, physiology, engineering, ergonomics, and medicine. The design and layout of displays and controls and the amount of workload can have an effect on the ability of the RLV flight crew to perform safety-critical functions. Using mockups, simulators, and training, and conducting human factors analyses such as functional and task analyses are examples of human factors-related applications to assess human-machine interfaces or human-in-the loop functions and performance. "DOD Design Criteria Standard – Human Engineering" (MIL-STD-1472), "Flying Qualities of Piloted Aircraft" (MIL-HDBK-1797), and "Man-Systems Integration Standards" (NASA-STD-3000) are examples of documents that may be used to provide guidance on applying human factors engineering.

b. RLVs shall be operated in a manner so that the crew can withstand physical stress factors (e.g., acceleration, vibration, noise) and not affect the RLV flight crew's capability to perform safety-critical functions.

Rationale: Excessive acceleration could result in loss of consciousness by the RLV flight crew depending on the magnitude and duration of the G-loads. Excessive noise could interfere with voice communication. "Man-Systems Integration Standards" (NASA-STD-3000) provide guidance on some of the physical stress factor limits.